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MILITARY GEOLOGY

Chapter 9. MILITARY ROADS

[Figures referred to herein are not reproduced but are available in the original document at the US Geological Survey.]

General

Terrain traversability and road networks are extremely important in the theatre of military operations. Napoleon was fond of saying, "The secret of war is the secret of communications," and "The strength of an army is measured by mass multiplied by speed."

In the section on fortifications we became acquainted with the means of fortifying a terrain with the aim of rendering it difficult of passage and converting it into an inaccessible area. In this chapter we shall be concerned with terrain traversability and the conditions for movement over it by various types of troops. In this matter the military geologist can aid greatly by giving the military experts specific data on the choice of the most suitable routes for roads and on the construction materials available in the vicinity of the projected roads.

In Table 18 all factors are given which should be taken into consideration in the combat theater in a summary appraisal of the traversability of terrain (relief, soils and grounds, rivers and lakes, marshes, woods, climate, etc.) The table also presents such peculiarities of relief as are not generally established in a morphological examination of the area -- namely, isotropism or anistropy of the landscape, i.e., the various degrees of difficulty of negotiating the area in predetermined directions.

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Table 18. Factors in Terrain Traversability

Relief	Soils and Grounds	Rivers and Lakes	Swamps	Forests	Climate	Characteristics	General Nature of Landscape
Commanding heights	Mechanical composition	Width, depth	Type of swamp Depth of solid ground	Species	Length of day and night	Lines of communication	Isotropism of area as affecting traversability
Slopes too steep for tanks	Cohesion	Speed of current	Thickness of peaty layer	Presence of undergrowth, density of crown	Air temperature, precipitation	Character of inhabited points	Anisotrophy of area as affecting traversability
Slightly scarped slopes	Viscosity, conditions of working	Behavior, thickness of ice	Muddiness Sponginess Stickiness	Average diameter of trunks	Fogs and cloudiness	Density of inhabited places	Surveyability of the area
Camouflage possibilities according to relief features	Presence of sod	Presence of fords	Characteristics of vegetation	Average distance between trees	Wind	Hydraulic-engineering network	
Degree of vertical and horizontal disjointedness of an area		Conditions of approach		Amount of rubbish in the forests, structural quality of wood			

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Roads have both strategical and tactical importance. In contemporary warfare of maneuver, any highway or railroad may become a military objective. When railroad trunk lines, stations, bridges, etc., have been knocked out by aerial bombing, automobile and wagon roads take on an enormous importance. The laying of new routes, the restoration of destroyed roads, the improvement of old roads -- those are the problems in the solution of which the military geologist must participate.

Military Communications

Lines of communication are the vital arteries which maintain an army. The experience of World War I showed that even in the period of positional warfare the army consumed a trainload of supplies per division daily, and in the period of active operations, up to 60 trains. To supply a division's combat activity for one day, an average of not less than 500-600 tons of ammunition is required, which constitutes one half of the general requirements. From October 1915 until 1, March 1917 on the Russian-German Front, 74,200 kilometers of dirt road were reconditioned, and 3,710 kilometers of trunk road and 318 kilometers of new pavement were constructed. The American Army in its short stay on the front in 1918 constructed 275 kilometers of new pavement, and restored 3,500 kilometers of old pavement. The daily requirement of crushed stone amounted to 3,000 tons.

In the Great War for the Fatherland, the scale of military road construction increased still more, and the destruction of lines of communication reached tremendous proportions.

The condition of roads must be taken into account for all movements and military operations. A plan of battle, either offensive or defensive, cannot be properly drawn up without an accounting of communications, i.e., without a consideration of the roads which link the front with the rear. There are engineer corps in all armies, whose basic task is to make secure the movement and maneuvering of troops. The geologist generally works as a part of the staff of the engineer corps or in contact with them.

Military communications include the entire system of supply routes -- railroads, water transport, and automobile roads. A diagram of communications in a combat zone is presented in Figure 73, p 196.

Cross-Country Routes of March

In the forward zone of a combat area the movement of troops is effected by specially constructed cross-country routes of march.

Cross-country routes of march are temporary roads of the simplest type, intended for movement of troop units with their materiel and for other types of transport.

Cross-country routes of march are constructed:

1. On the offensive, to secure the approach, through the defensive zone of the enemy, of infantry regiments, their regimental train, and artillery, and also for the transportation of troops and freight in the rear areas of regiments or divisions.

2. During preparations for the offensive, for tank units on their deployment to their positions of readiness and during the passage of an echelon with a mission to develop a breakthrough from the intermediate position to the line of departure and further to the zone of the breakthrough.

3. In movements by motor transport, in order to provide for movements in loading and unloading areas and the approaches to these areas.

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A great deal of work is required for the construction of cross-country lines of march in mountainous theatres of operation. Laying them out in the spring, when roads are bad, is also fraught with great difficulties. The roads become particularly important in winter.

The great importance of cross-country routes of march in the offensive was illustrated by the activity of the Red Army in 1942 in the liquidation of the so-called Demyansk Base of Operations. A hundred kilometers of road, over which our infantry, artillery, and automotive transport moved, were laid in a marshy, wooded area, with insufficiently frozen ground, in deep, loose snow.

Cross-country routes of march often cross new land and afford the simplest passage through natural and artificial barriers (swamps, rivers, irrigation ditches, etc.). The projected course of a cross-country route of march must satisfy the following conditions: (1) correspond to the given direction and be as short as possible; (2) provide or at least facilitate camouflage; (3) avoid areas which facilitate the accumulation of poison gas or which pass through defiles (without jeopardizing camouflage); (4) require the minimum outlay for their construction; (5) avoid intersection with other automobile and wagon roads; (6) proceed over the firmest possible ground (sandy, clayey soils, gravelly mixtures) so that the movement may proceed without road reinforcements; (7) secure the unhampered movement of the heaviest machines, motorized and mechanized forces, artillery, etc.

Infantry and tanks can move over almost any dry ground. Tanks can surmount grades of as much as 45 degrees. It is known from the experience of the Great War for the Fatherland that tanks were often immobilized on difficult ground in rainy weather. Cross-country routes of march for horse-drawn artillery can be laid through sufficiently firm virgin soil or plowed land. The cross-country route of march for mechanized divisional or regimental artillery with tractors weighing from 5 to 10 tons can be laid out in marshy ground if the ground supports a pressure of no less than 0.5 kilograms per sq cm. The basic elements of the cross-country routes of march are given in Table 19.

In the construction of cross-country routes of march one must take account of the engineering -- geological and hydrogeological conditions, the relief, and the presence of water obstacles and swampy areas.

In the autumn season of bad roads, the following rules must be observed:

1. To lay out the course along the watershed and places of firm ground (sands and sandy, clayey soils).

2. To avoid laying out the course through plowed fields, meadows, or areas flooded by spring high water.

3. To avoid clayey ground and black loams. (In grounds having a moisture content of 20-25 percent, machines of ZIS and GAZ models can move only in level areas or on slight grades; in sandy ground or sandy loam under the same conditions steeper grades can be negotiated.)

In wooded, marshy places cross-country routes of march must be laid along paths and lanes even if this means lengthening the way between two selected points, and also through places of minimum density of trees.

Laying out the course in marshy places entails considerable difficulty, especially for heavy automotive transport and artillery. Therefore, it is recommended that marshes be avoided if possible, or, if they must be crossed, that they be crossed at the narrowest place. In such a case the passages must be sufficiently wide, inasmuch as certain types of marsh become impassable after the passage of a few mechanized units over the same spot. We shall return to the question of traversability of swamps later.

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Table 19. Basic Elements of Cross-Country Routes of March

Purpose of Route	Flat Plain or Broken Terrain			Mountainous Terrain			Remarks
	Width of Passage (Meters)	Max grade (%)	Max Curve Radius (Meters)	Width of Passage (Meters)	Max grade (%)	Max Curve Radius (Meters)	
For movement of infantry, cavalry and equipment	2.5-3	10-15	30	1-2.5	20	10	Fording depth for cavalry, 1.2 meters; for infantry, 1 meter
For artillery, mechanized or horse-drawn	3-3.5	12-15	30	2-5.3	15	20	Motorized artillery can climb 12-15% slopes in exceptional cases [illegible] firm dry ground.
For tanks	3-4	15-12	15	2.5-3.5	20-15	15	In medium dense woods [illegible] or trees 25-50 cm di[illegible]eter, preliminary en[illegible]gineering preparatio[illegible] is required.
For motorized units and automotive transport	3-5	3-10	30	3-3.5	12-15	15-25	For automotive transport fording depth is minimum compared to other means of locomotion - 0.5 meter.

NOTES: In forested, marshy, and mount[illegible] terrain a clearing must be made every 200-300 meters for stalled machines.

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Bearing in mind that in the rainy season water seriously damages roads, it is necessary when constructing roads in mountainous regions to employ all means to prevent landslips of earth and rocks, crumbling, and the erosion of roads.

Motor- and Animal-Transport Roads

Motor- and animal-transport roads are classified according to surface: (1) dirt and gravel; (2) stone (chaussee, cobblestone, etc.), (3) improved roads (black-top chaussee, etc.), (4) superior roads (asphalt-concrete).

Table 20 gives a road classification in use in the USSR, showing the requirements of roads in varying relief landscapes.

Dirt roads are the prevailing type of road built in wartime. Improved roads and trunk-line roads are usually built in peacetime. Construction of dirt roads is reduced to the following operations: (1) clearing the road strip; (2) loosening hard ground; (3) longitudinal leveling; (4) lateral leveling of the roadbed; (5) grading the roadbed and packing the top layer; and (6) packing the road with a steam roller.

/The section which follows deals with military railroads. The pertinent data is summarized in Table 21./

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Table 20. Classification of State Automobile Roads in the USSR and of Standard Basic Elements of Roads

Class of Road and Nature of Terrain	Class I (Main Auto Roads)	Class II Plain	Class II Relief Broken	Class II Mountain	Class III Plain	Class III Relief Broken	Class III Mountain
Estimated speed in km/hour:							
a. Light motor vehicles in normal conditions	120	120	100	80	60	50	30
b. Light motor vehicles and trucks on slippery roads	80	65	50	25	40	35	20
Number of Lanes	4	2	2	2	2	2	2
Width of total right of way in meters	48	38	38	38	30	30	30
Width of traffic roadway in meters	14	7	7	6	6	6	6
Width of earth roadbed in meters	28	11	11	8	10	10	8
Radius of curves in %:							
a. Basic calculated	1500	1100	750	200	400	300	100
b. Minimum	500	400	250	60	150	100	35
Gradient limit in %:							
a. Maximum	3	4	5	6	4	5	7
b. In exceptional cases	4	5	6	7	5	7	8
Distance of visibility in meters:							
a. On the level	160	220	150	50	90	80	40
b. In profile	150	110	75	25	45	40	40

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Table 21. Technical Conditions for Projection and Building Military Field Railroads

(Data in abbreviated form)

Road Elements	Steam-Locomotive Traction	Diesel Locomotive or Horse Traction
Limitations of rise	Without distance limitation, 0.016. In especially difficult conditions on a stretch of not over 100 meters, 0.050	For Diesel engine, same as for steam. For horse traction, up to 0.020
Limitations of radius	50 meters; in stations, up to 40 meters	15 meters
Width of earth roadbed	2.5 meters for sandy fills. 2.10 meters for branches built for a short time	For Diesel engine, same as for steam; for horse traction, 4.2 meters; in deep hollows, 3.80 meters is permissible
Thickness of ballast layer	0.10-0.20 meters	0.10-0.20 meters
Width of ballast layer on top	1.60 meters	For Diesel engine 1.60 meters. For horse traction, 1.30 meters
Elevation of roadbed above level of highest water	0.30 meter	0.30 meters (In case lines are constructed for long duration)
Elevation of lower part of bridge girders above level of highest water	0.20 meter	0.20 meters
Distance between stations	10-16 meters; between railroad sidings, 5 km.	For Diesel engine, same as for steam. For horse traction, 25 km; between sidings, 12.5 km
Greatest gradient at stations	0.002	0.010

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Bridges and Water Crossings

Military bridges are divided into three classes: (1) bridges for attack, (2) bridges for convoy, (3) stationary bridges.

Bridges for attack are used in forcing a river crossing. Included in this group are tank bridges brought up in preassembled form by special engineering tanks and constructed in less than 1 minute under enemy fire without the crew's leaving the tanks.

Bridges for convoy are intended for the crossing of the main forces and are constructed on floating and rigid supports. Light bridges can take a maximum load of 20-30 tons; heavy bridges, up to 60-70 tons.

Stationary bridges are constructed along rear lines of communication on floating and rigid supports.

The most commonly used bridges constructed on dirt roads in a combat theatre are of the beam and brace type.

Military loads are classified as caterpillar loads (tanks, tractors) and wheeled loads (automobiles, artillery pieces). All standard bridges are divided in four classes on the basis of load capacity, as N1, N2, N3, N4, as shown in Table 22.

In computing the load capacity of bridges, the caterpillar-type loads are formed into a train. Thus, a first-class load (N 1) consists of a train made up either of caterpillar-type loads of 10 tons or of one wheeled type load with rear-axle pressure of 4 kg per sq cm.

Bridge materials are tested either with reference to a train of loads, an individual caterpillar load, or an axle, depending on which kind of load causes greater strain on the material which is being tested.

In combat areas, if a river forms a line of resistance, it is not always possible to construct a bridge; therefore troops are supplied with stream-crossing equipment (ferries, pneumatic floats, boats, etc.). In some cases disassembled bridges are used to set up bridges in important directions.

Troops often have to cross streams by fording, swimming, or, in winter, on ice. Tankettes can ford a stream no deeper than 0.05 meter; artillery and military trains, up to 0.70 meter; tanks (not amphibious), up to 0.90 meter; infantry, to 1 meter; and cavalry, up to 1.40 meters. Examples of heroic forcing of rivers under very unfavorable conditions can be cited from the Great War for the Fatherland, particularly the forcing of the Desna and the Dnepr. Tank units crossed the Desna at the fording depth of nearly 2 meters, simply by plugging up the tanks' apertures.

In making crossings on ice it is necessary to determine the ice's thickness and to beware of holes and breaks caused by shells and bombs. When ice is 5 to 10 cm thick, men spaced 2 meters apart can cross; with 10 to 15 centimeters of ice, horses and artillery can cross. With a thickness of 30 centimeters, any cannons and tanks can cross.

Geological and Soil Research in Road Construction

Technical road research is usually divided into three phases: (1) reconnoitering, (2) detailed study, (3) reduction.

Reconnoitering starts with a map study of the direction of a road. The line of the road course, the grades which can be climbed, bridges, mountain

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Table 22. Standard Military Loads

Type	Caterpillar Loads				Wheeled Loads		
	General Weight (in Tons)	Length of Caterpillar Tread (in Meters)	Width of Passage (in Meters)	Width of Caterpillar Tread (in Meters)	Pressure on Rear Axle (in Kg/Sq Cm)	Width of Passage (in Meters)	Width of Rim of Rear Wheel (in Meters)
N 1	10	3	2	0.25	4	1.5	0.2
N 2	40	4	2.25	0.25	6.7	1.5	0.2
N 3	30	5	2.5	0.50	10	1.7	0.4
N 4	45	5	2.5	0.50	15	1.7	0.4

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passes, etc., are marked on topographical maps. Investigation of the terrain is carried out by means of preliminary markings on maps. Actual surveying involves a study of the relief, the physico-geological phenomena which might constitute a threat to the road (landslips, avalanches, cavernous terrain, etc.), and swamps. Soil categories are studied from the point of view of road construction, and an appraisal is made of the conditions of travel on existing roads, etc. A number of alternative road courses must be considered in the study in order to have a basis for comparative evaluation.

The detailed study consists of spot surveys by instruments, in tracing lines on drafts with horizontals, in laying out the terrain, levelling the principal direction, etc.

Reduction work is carried out just before the construction of the road with the purpose of reducing the line, the introduction of necessary correctives in the road project, and preparing drawings and other documentation for the project.

Selection of the Route of the Road

A road between given points should be as nearly as possible a straight line. In peacetime, deviations may be justified by economic reasons; in wartime the basic requirements are speedy construction and assurance of troop movement. Furthermore, in projecting and constructing military roads, the demands of camouflage are imperative. Thus, the selection of the road's course is determined by a complicated combination of reasons, and a straight line will not always be the most desirable direction of a military road. Furthermore, the location of road materials must be considered as a factor in shortening the construction time.

The following factors determine the correctness of choice of the road's course:

1. The minimum amount of earth work and smallest number of bridges required.

2. The firmness and solidity of the soils and strata

3. Nearness of location of construction materials.

4. Suitability of the terrain for the camouflaging of the road and troop movements

Study of Soils and Grounds

In handling problems of road construction, the most convenient classification of soils is that of N. M. Sibirtsev, which divides all soils into three classes: zonal, intrazonal and azonal.

Class I, zonal soils: (1) tundra soils; (2) podsol soils; (3) transitional soils (between forest and steppe); (4) black-earth soils (steppe soils); (5) chestnut-brown and brown soils, grayish soils (soils of dry and semiarid steppes); (6) laterites (subtropical soils).

Class II, intrazonal soils: (1) saline soils ("solonets") soil and marshy soils [solodi]; (2) "solonchak" soils ("Solonchak") and brackish-marshy [solonchakovo-bolotnyye] soils; (3) marshy soils (peat, peaty-gley, meadow and oozy gleys); (4) gleyey-podzolic soils (semi-marshy); (5) dark-colored soils (black-earth type soils); (6) humus-carbonated soils.

Class III, azonal soils: (1) Alluvial soils (river); (2) eroded and washed soils; (3) coarse stony, gravelly, and pebbly soils; (4) pine-forest sandy soils;

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(5) surface outcropping and exposure of soil-forming strata.

In the distribution of soils it is necessary to take into account certain uniformities:

1. The law of horizontal soil zones (formulated by N. M. Sibirtsev). Soils occur in zones (or strips) which alternate from north to south.

2. The law of vertical soil zones (proposed by V. V. Dokuchayev). Given two slopes the bases of which have similar geological characteristics, the succession of soil types along each slope will also be similar.

3. The law of soil microzones (Academician Afanas'yev). In small relief depressions soils are disposed in the form of miniature vertical zones.

All three of these laws can be combined in one general law of analogous topographical series of soils (a vertical zones corresponds to each horizontal zone.)

4. The law of reversal of soil zones (M. M. Filatov and I. M. Krasheninnikov). The disposition of mountainous regions and ridges and the direction of slopes bring about a transposition and displacement of soil zones both vertically and along the slopes, depending upon orientation with relation to the points of the compass.

5. The law of soil regions (L. I. Prasolov). As a consequence of local physical geographic conditions, soil zones are divided into more or less extended regions often far removed from each other.

Field examination of the soils is carried out with the aid of small prospecting pits and pit-holes. The prospecting pits are 0.80 meter by 1.70 meters in cross section and are generally sunk to a depth of 1.5 to 2 meters. One of the sides is located facing the sun, which permits a careful study of all the morphological characteristics of the soil and a separation of genetic levels and sublevels. Specimens are gathered at the same time. Control pits (half-pits) are dug less deeply — to a depth of one meter (cross section 0.65 meter by 1.30 meters).

Records of the examination are kept according to a definite form. (Table 23)

In addition to the granulometric properties of the soil it is also necessary to take into account the electrochemical processes taking place in connection with capillary phenomena. These phenomena differ in soils of dissimilar origin, even though the granulometric composition of these soils may be similar.

Traversability of Swamps and the Construction of Roads Through Swamps

Widespread marshy areas and swamps are to be found in regions of excessive moisture, mainly in the forest zone of temperate climate geographically connected with the Quaternary glacial region.

Swamps occupy a vast part of the territory of the USSR. They are found in the southernmost steppe regions, where swampy bottomlands, called "plavni," have developed in the lower parts of the Dnepr, Don, and Kuban Rivers. Inundations occur even in semiarid regions where usually dry rivers bring down in springtime a great volume of water which accumulates in the low places. This is the way salt lake-swamps, of the type found in Kazakhstan are formed.

The following data is needed for military road construction through swamps:

1. Designation of the swamp and geographical location, distance from inhabited places or other orientation points.

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Table 23. Field Journal Form

(For Soil Research in Road Construction)
(First Page)
Prospecting Pit No

Date ____________

Km ____________ pk ____________ Plus ____________ Right ____________ Left ____________ m ____________

1. Relief of area ____________
2. Relief element in which prospecting pit is sunk ____________
3. Type of land and vegetation ____________
4. Type of ground-soil and name of basement rock ____________
5. Hydraulic conditions (surface drainage, susceptibility to flooding, etc.) ____________
6. Subsoil water level when unearthed ____________

   Settling point (date) ____________

   Gleying ____________

(Second Page)

No of specimen and depth of sampling	Vertical cross section	Name of genetic level	Thickness in centimeters	Color tint	Granulometric composition	Moisture and its characteristics (level of subsoil waters)	Thickness according to the accepted scale	Structure and its thickness	New formations, admixtures, scouring	Evaluation of construction properties of ground
1	2	3	4	5	6	7	8	9	10	11

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Table 24. Granulometric Classification of Soils of the Section of Animal-Traction and Paved Roads of the MKVD, USSR

Soils	Contents of components in % by weight		
	Sandy (2.00 - 0.05 mm)	Dusty (0.05 - 0.005 mm)	Clayey (less than 0.005 mm)
Sandy		Less than 15%	Less than 3%
Sandy-dusty		15-50%	Less than 3%
Sandy-loam	Particles 2.00-0.25 mm over 50%	Less than in sandy	3-12%
Fine sandy-loam	Particles 2.00-0.25 mm less than 50%	Less than in sandy	3-12%
Dusty		Greater than in sandy	Less than 12%
Clayey	Greater than dusty		12-18%
Heavy clayey	Greater than dusty		18-25%
Dusty clayey		Greater than sandy	12-25%
Clayey			over 25%

NOTE: 1. For construction purposes sands are divided into four types:
- a. Coarse sand -- with more than 50% of particles from 2-1 mm
- b. Medium sand -- with more than 50% of particles larger than 0.5 mm
- c. Small sand -- with less than 50% of particles larger than 0.5 mm
  Small sand -- with more than 50% of particles larger than .25 mm
- d. Very small sand -- with more than 50% of particles smaller than .25 mm

2. Soils composed of over 10% of particles larger than 2 mm belong in the gravelly or stony type.

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2. Geomorphological characteristics of the landscape of the area, peculiarities of the meso- and micro relief, the presence of hillocks and stagnant pools. It is necessary to indicate the origin of the relief element with which the swamp is connected (whether it is the product of glaciation or the activity of existing rivers, etc.)

3. Vegetation: kind of trees, approximate diameter, etc., grassy covering

4. Conditions of water supply of the swamp (direction of the surface run-off and the average degree of slope of the swamp's surface)

5. Presence of drainage networks

6. Thickness and nature of the peat, its carrying power and the ground of the swamp's base

In choosing a crossing through a swamp one should be guided by the following considerations:

1. The swamp should be crossed at its narrowest point.

2. The route should cross the swamp at its shallowest point (usually this is the same as the narrowest point).

3. The roads should be laid where the swamp bottom lies horizontally.

4. The height of the embankments must be determined in such a way that the rim of the finished roadbed will rise above the bottom of the embankment no less than 0.5 meter above the capillary rise level of the water in the ground of the embankment.

Establishment of a Drainage System

The establishment of a proper system of drainage, upon which the regular functioning of the road depends, is of basic importance.

Lateral ditches, cut as trapezoids or triangles, serve to lower the level of subsoil water or to drain off water flowing from the surface of the roadbed or the slopes of excavations. Ditches may be dispensed with only when the road is located on an embankment (over 0.5 meter high) of sandy or gravelly ground affording good drainage. When contending with fast-flowing water, the ditches should be reinforced. Their depth depends upon the nature of the soil and the width of the earth roadbed. (See Table 35, p 229).

Special drainage systems are constructed to protect the base from being soaked by subsoil waters, especially in ground which has high capillarity or a marked tendency to form chasms. The depth of the drainage system depends upon the level of the water table, the capillary peculiarities of the soil and the depth of freezing.

The requirements of drainage of a military road will then depend upon (1) the condition of the weather and the weather forecast for the set period of use of the road; (2) the relief features of the area; (3) the level of the water table; and (4) the soil.

Causes of Deterioration of Roads

To insure the continuous use of roads they must be regularly inspected and repaired. All dirt roads except sand roads deteriorate in wet weather; clay roads may become impassable with deep mud. Even paved roads are subject to complete destruction by use and from the weather. The following recommendations are made for maintaining roads in good shape: (1) use of the whole width of the road by vehicles, not just one track; (2) setting apart a separate route for motor transport; (3) inclusion within motorized columns of special machines which level off ruts and holes in the road; (4) spraying dirt roads in dry weather with a solution of calcium chloride (20 percent concentration) in the amount of 0.8 to 1.1 kg per sq meter. Calcium chloride, being hygroscopic, causes hardening of the ground and minimizes dust formation.

__Appraisal of the Elements Affecting Traversability in the Theater of Military Operations__

An appraisal of the traversability of a region and of the conditions affecting road construction should be made in the light of past and future combat operations in a given area of the theater of military operations. It is necessary also to take into consideration the high degree of mechanization of armored and engineering troops.

In wartime, the work of the geologist in road-survey crews acquires particular importance. The geologist must often give detailed analyses and surveys and make accurate and bold decisions in the field, immediately and without preparation. This enhances still more the importance of geological work in highway matters during a period of military operations.

The geologist concerned with problems of traversability and with the exploration of cross-country routes of march, fords, crossings, etc., must not be confined within the narrow limits of his specialty, since geological factors are only aspects of traversability and not always the most important aspects. Questions of soil science, terrain, climate, vegetation, and hydrogeology are of no less importance. The geological service of military highways must, on the one hand, be based on a thorough analysis of the landscape of the region, which reflects a complex of phenomena, and, on the other, must utilize the latest methods of studying the physical and mechanical characteristics of soils. The geologist must be acquainted with methods of highway construction and with measures for improving the quality of roadbeds (stabilization of soils) since roads must be built even under the most adverse conditions and on unstable ground.

The geologist should exhibit great initiative in searching for local material for ground reinforcement. The charts of road traversability should include such factors as geomorphological conditions (for example a slope steeper than 30 degrees, ground soil, deposits of construction materials for the paving and improvement of roads, highways, vegetation, swamps, salt marshes, rivers (fords)-- in a word, everything that is necessary for an accurate appraisal of the traversability of the region.

In the various landscape zones it is necessary to give a clear account of the relative importance of isolated elements affecting traversability, as follows:

1. Morphology and Geology

These elements are of importance principally in mountainous countries. Every mountainous country has its own morphologic and tectonic structure which determines the conditions of traversability.

The treat of encirclement possesses great importance in mountain warfare and is a problem for defense. Therefore, it is important here to make an appraisal of passes and narrow defiles which hamper maneuverability. Terrain conditions in the mountains conform to specific vertical zoning, which must be determined with the maximum possible care, since the boundaries between zones are not established merely by horizontal and absolute marks, but show many variations depending on the asymmetry of slopes, their exposure, the azimuth direction of a mountain range, and the whole range of artificial elements produced by the hand of man (the felling of woods, fields, plowed land).

It is necessary to distinguish within the boundaries of the vertical

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landscape zones geomorphologic complexes, whose peculiarities are identified by geologic formations. Here it is important to point out not only the composition of the rock, but also its stratification. Alpinists well know how much easier it is to scale granite cliffs than shale.

2. Ground-Soil Conditions

These conditions are of predominant importance in steppe, semiarid, and arid zones. An appraisal of the traversability of ground soils involves the consideration of:

a. Horizontal and vertical zonation of soils

b. Natural cohesion of soils and grounds

c. Extent to which bad roads are produced during wet weather

d. Degree of soil and ground stability during dry weather with regard to formation of dust

e. Conditions of soils and grounds typical of given areas (dryness, wetness, time and duration of the season of bad roads, etc).

3. Climatic Factors

The study of climatic factors is carried out by the hydrometeorological service. Although these factors do not constitute a basic objective for geological investigation it is necessary to take them into account for a complete appraisal of the traversability of a region. Problems of saturated ground, dust, the appearance of snow cover, chasms -- all these are linked with hydrometeorological conditions.

Snow cover is of prime importance among meteorological factors affecting the traversability of mountainous regions. The most significant phases of the location of the snow line must be plotted on the chart of the elements of traversability. In northern regions the beginning and duration of the frost period is of great importance. Marshes and rivers in these regions may serve as good communication routes during frost periods. Consequently, it is important to record the time of freezing and thawing of the rivers, the thickness of the ice, etc. (These data can be recorded in the form of isolines on charts.)

Particular attention should be paid to weather forecasts. The success of operations frequently depends on weather forecasts. In particular, the settling of fogs has great importance for the success of sudden operations. Fogs covering the rivers morning and evening and remaining for prolonged periods on lakes effectively mask operations on water from aerial observation and thus aid crossings.

4. Vegetation

This element must be considered together with morphological and ground-soil conditions. In forested regions vegetation is one of the main factors affecting traversability. It is necessary to distinguish:

a. Swamp vegetation
b. Woods and scrub
c. Grassy vegetation (meadow, steppe, and desert)
d. Cultivated vegetation (gardens, parks, crops, vineyards, corn fields, etc.).

Plant cover developed on areas of land influences road characteristics both positively and negatively. In the first case, grassy vegetation forms a sturdy

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and facilitating traversability. In the second, the presence of hillocks in swampy meadows hampers movement.

5. Bodies of Water

Rivers, lakes, and swamps are important elements affecting traversability. Without a careful study of these objects, their banks and their genetic peculiarities, it is impossible for the geologist to offer advice in the selection of crossings and bridges. Sloping banks permit transport to cross at almost any place on a river. Steep, abrupt, and rocky banks complicate passage across water barriers. Swamp areas on the banks of a river hamper the movement of transport.

6. Means of Communication

A network of roads of various types is necessary for the facilitation of traversability of territory in the theater of operations. The geologist participates in the selection of the course of the road and in its construction. In a number of instances he may be called upon to appraise the traversability of the territory held by the enemy. Without consideration of routes of communication such an appraisal would be incomplete, and this obliges the geologist to be sufficiently familiar with all types of roads and with the elements affecting their construction. Furthermore, construction assists in establishing certain peculiarities of the natural conditions of the landscape (size of a valley, the width of rivers, the steepness of slopes, etc.).

At the same time, it is necessary to know the methods for the most rapid restoration of roads. Basic types of obstructions or obstacles which may be encountered on roads in war time are:

a. Mined and contaminated fields

b. Sections with landslides, obstructions, barriers, fissures, craters, etc.

c. Sections with various types of wire obstructions

d. Ground strewn with broken glass, thorns, and spikes

e. Sections with water obstacles and artificial glaze

Tracing of road boundaries is a preliminary step in the work of restoration of a road. The geologist may be consulted in planning detours of damaged sections of roads and also in searching for local deposits of handy mineral construction materials for repairing roads, filling in craters from projectiles and bombs, and reclaiming swamped sections of roads, etc.

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